2.0 TECHNOLOGY SELECTION PROCESS

The Federal Remediation Technologies Roundtable website was researched for available technologies and level of success on field scale projects. All of the technologies were also subjected to the additional criteria and constraints:

- Success in treating BTEX and MTBE,
- In situ process,
- Maximum flexibility,
- No effluent (regardless of quality) discharge to sewer,
- Reliability,
- Simple operations,
- Minimal maintenance,
- Reasonable cleanup time, and
- Overall cost.

Based on this review, the following technologies were selected for potential implementation. Descriptions and limitations for each technology are summarized in the following (from the FRTR, Remediation Technologies Screening Matrix and Reference Guide, Version 4.0):

2.1 BIOVENTING

Oxygen is delivered to contaminated unsaturated soils by forced air (either extraction or injection of air) to increase oxygen concentration and stimulate biodegradation. Factors that may limit the applicability and effectiveness of the process include:

- The water table within several feet of the surface, saturated soil lenses, or low permeability soils reduce bioventing performance.
- Vapors can build up in basements within the radius of influence of air injection wells. Extracting air near the structure of concern can alleviate this problem.
- Extremely low soil moisture content may limit biodegradation and the effectiveness of bioventing.
- Monitoring of off-gases at the soil surface may be required.
- Aerobic biodegradation of many chlorinated compounds may not be effective unless there is a co-metabolite present, or an anaerobic cycle.
- Low temperatures may slow remediation, although successful remediation has been demonstrated in extremely cold weather climates.

2.2 ENHANCED BIOREMEDIATION

Increasing the concentration of electron acceptors and nutrients in water, surface water, and leachate enhances the rate of bioremediation of organic contaminants by microbes. Oxygen is the main electron acceptor under aerobic bioremediation. Nitrate serves as an alternative electron acceptor under anoxic conditions. Oxygen enhancement can be achieved by either sparging air below the water table or circulating hydrogen peroxide (H_2O_2) throughout the contaminated groundwater zone. Under anaerobic conditions, nitrate is circulated throughout the groundwater contamination zone to enhance bioremediation. Additionally, solid-phase peroxide products [e.g., oxygen releasing compound (ORC)] can also be used for oxygen enhancement and to increase the rate of biodegradation. Factors that may limit the applicability and effectiveness of these processes include:

- Where the subsurface is heterogeneous, it is very difficult to deliver the nitrate or hydrogen peroxide solution throughout every portion of the contaminated zone. Higher permeability zones will be cleaned up much faster because groundwater flow rates are greater.
- Safety precautions must be used when handling hydrogen peroxide.
- Concentrations of hydrogen peroxide greater than 100 to 200 ppm in groundwater are inhibiting to microorganisms.
- Microbial enzymes and high iron content of subsurface materials can rapidly reduce concentrations of hydrogen peroxide and reduce zones of influence.
- A groundwater circulation system must be created so that contaminants do not escape from zones of active biodegradation.
- Because air sparging increases pressure in the vadose zone, vapors can build up in building basements, which are generally low-pressure areas.
- Many states prohibit nitrate injection into groundwater because nitrate is regulated through drinking water standards.
- A surface treatment system, such as air stripping or carbon adsorption, may be required to treat extracted groundwater prior to re-injection or disposal.

2.3 SOIL VAPOR EXTRACTION (SVE)

Vacuum is applied through extraction wells to create a pressure/concentration gradient that induces gas-phase volatiles to be removed from soil through the extraction wells. Also known as in situ soil venting, volatilization, enhanced volatilization, or soil vacuum extraction. Factors that may limit the applicability and effectiveness of the process include:

- Soil that has a high percentage of fines and a high degree of saturation will require higher vacuums (increasing costs) and/or hindering the operation of the in situ SVE system.
- Large screened intervals are required in extraction wells for soil with highly variable permeability or stratification, which otherwise may result in uneven delivery of gas flow from the contaminated regions.
- Soil that has high organic content or is extremely dry has a high sorption capacity of VOCs, which results in reduced removal rates.
- Exhaust air from in situ SVE system may require treatment to eliminate possible harm to the public and the environment.

- As a result of off-gas treatment, residual liquids may require treatment/disposal. Spent activated carbon will definitely require regeneration or disposal.
- SVE is not effective in the saturated zone; however, lowering the water table can expose more media to SVE (this may address concerns regarding LNAPLs).

2.4 AIR SPARGING

Air is injected into saturated soils to remove contaminants through volatilization. Factors that may limit the applicability and effectiveness of the process include:

- Airflow through the saturated zone may not be uniform, which implies that there can be uncontrolled movement of potentially dangerous vapors.
- Depth of contaminants and specific site geology must be considered.
- Air injection wells must be designed for site-specific conditions.
- Soil heterogeneity may cause some zones to be relatively unaffected.

2.5 BIOSLURPING

Bioslurping combines the two remedial approaches of bioventing and enhanced free-product recovery. Bioventing stimulates the aerobic bioremediation of hydrocarbon-contaminated soils. Vacuum-enhanced product recovery extracts LNAPLs from the capillary fringe and the water table. Factors that may limit the applicability and effectiveness of the bioslurping process include:

- Bioslurping is less effective in tight (low-permeability) soils.
- Low soil moisture content may limit biodegradation and the effectiveness of bioventing, which tends to dry out the soils.
- Aerobic biodegradation of many chlorinated compounds may not be effective unless there is a co-metabolite present.
- Low temperatures slow remediation.
- Frequently, the off-gas from the bioslurper system requires treatment before discharge. However, treatment of the off-gas may only be required shortly after the startup of the system as fuel rates decrease.
- At some sites, bioslurper systems can extract large volumes of water that may need to be treated prior to discharge depending on the concentration of contaminants in the process water.
- Since the fuel, water and air are removed from the subsurface in one stream, mixing of the phases occurs. These mixtures may require special oil/water separators or treatment before the process water can be discharged.

2.6 BIOFILTRATION

For air emissions/off-gas treatment, vapor-phase organic contaminants are pumped through a soil bed at the soil surface where they are degraded by microorganisms in the soil. The following factors may limit the applicability and effectiveness of the process:

- The rate of influent airflow is constrained by the size of the biofilter.
- Fugitive fungi may be a problem.
- Low temperatures may slow or stop removal unless the biofilter is climate-controlled.
- Compounds that are recalcitrant to biodegradation will not be converted to harmless products.